

CASE NO.: Y0R20000609US2

Serial No.: 09/943,896

September 22, 2005

Page 2

PATENT
Filed: August 31, 2001

1. (currently amended) [[An]] A fingerprint image enhancement process comprising the steps of:

establishing plural sub region filters using a learning process, the learning process including obtaining a representative set of fingerprints and establishing, using a human or machine expert, a corresponding set of desired maps, a set of filters being developed therefrom;

a windowing process that selects a sub-region of an image partitioning the image into sub regions, each sub region representing a portion of a fingerprint image;

for at least some sub regions, determining a value for each of one or more fingerprint image characteristics of the sub regions, the characteristics being of a subject of the sub region;

using the values, classifying at least some sub regions into defining one or more classes of the sub-region from the values;

selecting one or more transform respective filters obtained using the learning/training process, that corresponds to for each respective class; and

for each sub region having a class, convolving the respective portion of the fingerprint image with the respective filter or filters successively applying the transform filter to the sub region having the same class as the transform filter to obtain a transformed sub region.

2. (original) The process, as in claim 1, where two or more transformed sub regions are combined to produce an enhanced sub region.

1201-12.AMD

CASE NO.: Y0R20000609US2
Serial No.: 09/943,896
September 22, 2005
Page 3

PATENT
Filed: August 31, 2001

3. (original) The process, as in claim 2, where the transformed sub regions are combined using a weighted summation of the transformed sub regions.

4. (currently amended) The process, as in claim 1, where one or more of the sub regions are determined by any one or more of the following: a pixel-wise amplitude of the sub region, an average amplitude of the sub region, an image frequency of the subregion, an orientation of the sub region, an amplitude transition transition in the orientation direction, a local contrast, a local phase, a scalar quantization of intensity values of the sub region, a vector quantization of intensity values of the sub region, a dryness measure of the sub region, a smudge measure of the sub region, a quality of the sub region, an average amplitude of the entire entire image, an average frequency of the entire image, an average quality of the entire image, and an average orientation variation of the entire image.

5. (original) The process, as in claim 1, where a number of the sub regions is determined by any one or more of the following: a pixel-wise amplitude of the sub region, an average amplitude of the sub region, an image frequency of the subregion, an orientation of the sub region, an amplitude transition in the orientation direction, a local contrast, a local phase, a scalar quantization of intensity values of the sub region, a vector quantization of intensity values of the sub region, a dryness measure of the sub region, a smudge measure of the sub region, a quality of the sub region, an average amplitude of the entire image, an average frequency of the entire image, an average quality of the entire image, and an average orientation variation of the entire image.

1201-12.AMD

CASE NO.: YOR20000609US2

Serial No.: 09/943,896

September 22, 2005

Page 4

PATENT
Filed: August 31, 2001

6. (original) The process, as in claim 1, where a shape of the sub regions are determined by any one or more of the following: a pixel-wise amplitude of the sub region, an average amplitude of the sub region, an image frequency of the subregion, an orientation of the sub region, an amplitude transition in the orientation direction, a local contrast, a local phase, a scalar quantization of intensity values of the sub region, a vector quantization of intensity values of the sub region, a dryness measure of the sub region, a smudge measure of the sub region, a quality of the sub region, an average amplitude of the entire image, an average frequency of the entire image, an average quality of the entire image, and an average orientation variation of the entire image.

7. (original) The process, as in claim 1, where an extent of overlap one or more of the sub regions is determined by any one or more of the following: a pixel-wise amplitude of the sub region, an average amplitude of the sub region, an image frequency of the subregion, an orientation of the sub region, an amplitude transition in the orientation direction, a local contrast, a local phase, a scalar quantization of intensity values of the sub region, a vector quantization of intensity values of the sub region, a dryness measure of the sub region, a smudge measure of the sub region, a quality of the sub region, an average amplitude of the entire image, an average frequency of the entire image, an average quality of the entire image, and an average orientation variation of the entire image.

8. (currently amended) The process, as in claim 1, where the characteristics are image characteristics that include any one or more of the following: a pixel-wise amplitude of the sub region, an average amplitude of the sub region, an image frequency of the subregion, an orientation of the sub region,

1201-12.AMD

CASE NO.: Y0R20000609US2
Serial No.: 09/943,896
September 22, 2005
Page 5

PATENT
Filed: August 31, 2001

an amplitude transition in the orientation direction, a local contrast, a local phase, a scalar quantization of intensity values of the sub region, a vector quantization of intensity values of the sub region, a dryness measure of the sub region, a smudge measure of the sub region, a quality of the sub region, an average amplitude of the entire image, an average frequency of the entire image, an average quality of the entire image, and an average orientation variation of the entire image.

9, 10 (canceled).

11. (currently amended) The process, as in claim 1, where the transform filter is chosen from a class that is near to the selected class (e.g., ~~when the filter specified sub-region class is not available due to lack of training data, or when choice of multiple transformation filters is available due to overlapping image division process~~).

12. (currently amended) The process, as in claim 11, where near is defined by any one or more of the following: a least square distance, an absolute distance, and an ordinal distance.

13. (original) The process, as in claim 1, where the characteristic is amplitude and the value is an amplitude intensity value.

14. (original) The process, as in claim 1, where the characteristic is the ridge orientation in a neighboring subregion and the value is orientation of the ridge with respect to x-axis in t-multiples of degrees.

1201-12-AMD

CASE NO.: Y0R20000609US2

Serial No.: 09/943,896

September 22, 2005

Page 6

PATENT
Filed: August 31, 2001

15. (original) The process, as in claim 14, where $t=90$.

16. (original) The process, as in claim 1, where the characteristic is image frequency and the value is a cycle per distance value.

17. (original) The process, as in claim 1, where the characteristic is a quality and the value based on an image type.

18. (original) The process, as in claim 1, where the characteristic is a texture and the value is based on a pattern repetition value.

19. (currently amended) The process, as in claim 1, where the characteristic is an amplitude transition and the value is one of a positive, negative, and zero.

20. (currently amended) The process, as in claim 1, where the characteristic is a perpendicular amplitude transition and the value is one of a positive, negative, zero.

21. (original) The process, as in claim 1, where the characteristic is an orientation variation and the value is the standard deviation of orientations in the neighborhood.

1201-12.AMD

CASE NO.: Y0R20000609US2
Serial No.: 09/943,896
September 22, 2005
Page 7

PATENT
Filed: August 31, 2001

22. (original) The process, as in claim 1, where one or more of the transformed filters is applied more than once to obtain the transformed sub region.

23. (original) The process, as in claim 22, where the number of times the transform filter is applied is predetermined.

24. (currently amended) The process, as in claim [[22]] 1, where the set of filters is developed using a least squares fit. transform filter is applied until a condition is met.

25-37 (canceled).

38. (new) A method of fingerprint image enhancement, comprising:
learning a set of partitioned least-squares filters derived from a given set of fingerprint images and expert-developed ground truth pairs; and
for each of at least some sub regions of a fingerprint image, convolving at least one respective filter with an input fingerprint image of the sub region to obtain an enhanced image.

39. (new) The method of Claim 38, wherein a filter is defined by

$$w = (X^T X)^{-1} X^T Y,$$

wherein k represents a sub region, x_i is a vector given by $[x_{1i}, x_{2i}, \dots, x_{ji}, x_{ki}]$, where x_{ji} is the image intensity at the j-th location within the i-th sub region; and further wherein

1201-12.AMD

CASE NO.: Y0R20000609US2
Serial No.: 09/943,896
September 22, 2005
Page 8

PATENT
Filed: August 31, 2001

y_i is the enhanced intensity at pixel i , provided by a fingerprint expert, and wherein
 X is a matrix defined by $[x_1, x_2 \dots x_i, x_M]^T$, Y is a matrix defined by $[y_1, y_2 \dots y_i, y_M]^T$,
where M is the number of candidate pixels from a class of the sub region and T is a transpose
of a matrix or vector.

1201-12.AMD